CHAPTER

3

The Benefits and Risks of Distributed Generation

In combination, falling costs, concerns about the reliability of utility-supplied power, and opportunities associated with electricity market restructuring have stimulated interest in using distributed generation technologies differently in the future from how they are typically used today. Rather than supplying emergency backup or exploiting only the largest-scale combined heat and power projects, small customer-owned generators could run regularly as a complement to utility-supplied power.

That new role could be filled in a number of ways, depending on the utility tariff, the technology used to generate electricity, and customers' power needs.[1] For example, with a utility tariff under which retail prices varied between on-peak and off-peak periods of demand (called a time-of-use tariff), operators of distributed generators could provide power during periods of peak demand when prices were high but rely on electricity from the grid to meet their "base load" (basic power) needs. Alternatively, under a non-time-of-use tariff, operators could run their distributed generators continuously to supply base loads and rely on grid-supplied power to meet peak needs. Or, in a third configuration, wind- or solar-powered systems could generate power intermittently, with operators buying supplemental power from the grid when on-site production was low and selling excess power over the grid when production exceeded on-site loads. Each of those new ways of integrating distributed generation and utility operations shares the features that the generator would operate regularly and would primarily serve the customer's own load, running in parallel (that is, while interconnected) with regular service to and from the grid.

Distributed generation, operated as a complement to traditionally supplied power, may offer significant benefits. It could lower the nation's overall costs of producing and delivering power. It could also promote the development and use of renewable energy sources and fuel-efficient technologies, which could improve the quality of the air and the security of the nation's energy supply.

Initiatives to realize those broader benefits entail risks, however. If rules and incentives intended to encourage the cost-effective installation and operation of distributed generation are poorly designed, they may raise the total costs of producing and delivering power. Depending on the outcome of the ongoing restructuring of electricity markets and other developments, such as the course of technological innovation, the potential economic benefits of distributed generation may diminish. There is also a significant likelihood that, among the several distributed generation technologies, systems fueled by fossil energy will dominate because they cost less than renewable technologies in most situations. In that case, the environmental benefits that some proponents of distributed power expect may not be realized.

1. A utility tariff is a schedule of prices for electricity, which may include such components as a minimum or fixed monthly fee for service, different prices per kilowatt-hour for electricity consumed in defined periods and quantity ranges, and a price per kilowatt for the maximum consumption (termed a demand charge) during a short (for example, 15-minute) interval per billing period.

Potential Savings in the Production and Delivery of Electricity

Systemwide cost savings may be possible if the ability to generate their own electricity leads retail customers to reduce their demand for utility-supplied power when wholesale electricity costs are high. The savings could result from the substitution of low-cost generating technologies for higher-cost ones and the avoidance of some costs associated with transmission and distribution.

Lower Costs of Generation

Whenever homes and businesses produce electricity on their own, utilities avoid the costs of purchasing or directly producing that electricity for those customers but lose the revenues from those sales. Under current cost-of-service regulations, any net savings or losses are typically passed on to all the utilities' customers through lower or higher retail prices. Thus, if customers can be induced to install and run distributed generators when their operating costs are lower than the utilities' wholesale costs, the retail price of electricity will fall for all customers.

Systemwide savings may be enhanced if the generation of electricity for customers' own use is flexible—the generator can increase output at certain times of the day or in certain seasons, when the demand from all customers for utility-supplied power is greatest. Additional savings will result because utilities generally operate their most expensive power plants during those peak periods. The unit costs of electricity production increase as utilities successively call on base-load generators, "peaking" generators, and older units, as well as push the utilization of all units to high levels. Because they can be switched on and off easily, distributed generators powered by internal combustion engines are most likely to help "shave" the peak and allow utilities to avoid using generators with very high marginal costs (the costs of supplying an additional unit of electricity).

Avoided Investment and Operating Losses in Transmission and Distribution

Distributed generation can reduce the need for sometimes significant investment in transmission and distribution lines and equipment to meet growing loads or to relieve congestion at certain points in the electric system. The costs of those investments can add significantly to the price of power delivered by utilities to retail customers. For example, in regions where transportation charges are broken out from the charges for the electric power itself, the average charge for transmitting and distributing the electricity (2.4 cents per kilowatt-hour) is more than 30 percent of the average price of delivered electricity (7.9 cents per kilowatt-hour).[2]

Retail electric utilities as well as their customers could use distributed generators to avoid or defer investments at the local level. For example, to meet seasonally high demand, a utility could install a small-capacity generator at a site on the distribution portion of its network instead of investing in increased capacity of "upstream" power lines and transformers. Utilities have recognized that small generators can be used to relieve periodic local congestion in the subtransmission and distribution portions of the electricity network. Such use can be a cost-effective alternative to investment in additional transformer capacity and other distribution infrastructure—often delaying the need for such upgrades.

In other cases, local utilities may want to install and operate distributed generators because building new transmission capacity raises environmental concerns. That use of distributed generation could prove especially valuable in places where opposition from environmental groups was constraining or delaying the construction of additional transmission capacity.

Wider adoption of distributed generation also would reduce power losses from the transmission and distribution of electricity between central power plants and customers. Those losses result from electrical resistance in the transmission and distribution system and from changes in voltage as the power approaches the point of consumption. The Energy Information Administration estimates that transmission and distribution losses in the United States averaged almost 7 percent of gross production (in gen-

2. Department of Energy, Energy Information Administration, *Electric Sales and Revenue 2000,* DOE/EIA-0540(00) (January 2002), Table C-1, p. 256.

erated kilowatt-hours) in 1999.[3] During hot weather (which is typical of summer peak periods), power lines stretch and conductivity diminishes, causing losses that can exceed 15 percent.

Additional Savings from Incentives for Adjusting Demand

Distributed generation gives customers an alternative to traditional utility-supplied electricity. Customers could use that on-site power source to increase the reliability of their electricity supply. That use could bolster economic efficiency because only customers who required increased reliability would have to pay for it. Customers could also generate their own power to help offset the impact of high electricity prices. More generally, that approach would provide a means by which retail customers and utilities could curtail their demand for power in regional electricity markets and possibly avert disruptions and price spikes. Even moderate changes in demand and supply, net of customer-owned generation, could significantly lower electricity prices in regional spot markets during periods of peak demand.

Improved Reliability of Service

Under the current supply system for electric power, utility distribution companies largely determine the basic level of service reliability for all customers in a given area. Utility planners typically establish a reliability target for their power generation and distribution network. They design and build the network with capacity margins and redundancies to meet that target, given estimated probabilities of failures and of capacity deficits for each component of the system. As a result, most customers receive electricity service with a similar reliability level, and the cost of that reliability is typically borne by all customers through their general charges. A customer not wanting that level of reliability cannot avoid its cost. If a customer needs a higher level of reliability, the utility can provide it only at a cost that is imposed on all customers.

Distributed generation offers an alternative solution. Customers who need highly reliable power can install distributed generators, allowing them to obtain uninterrupted service without imposing their requirements and associated costs on other customers. In California, for example, where customers have historically had an average of fewer than two significant outages per year (defined as outages of at least five minutes' duration, as measured by the system average interruption frequency index), there are more than 4,000 backup generators larger than 300 kilowatts (approximately equivalent to a 450-horsepower motor).[4] That 300-kilowatt capacity is large enough to supply most large commercial and medium-sized industrial customers.

The potential for using distributed generation to meet reliability needs could be enhanced through measures that permitted nonemergency operation of the units. Such an approach would allow owners to operate their generators when it was cost-effective and to reduce the net cost of reliable service.

Reductions in the Volatility of Wholesale Prices

The limited incentive for retail electricity customers to reduce consumption when wholesale prices rise contributes to the volatility of wholesale electricity prices. If retail customers had the capability to adjust their net demand for utility-supplied power through distributed generation and had the necessary incentives to do so through time-varying tariffs, such as real-time pricing or time-of-use tariffs, then wholesale prices would be less volatile and lower, on average.[5] In particular, wider use of distributed generation would tend to reduce the size and frequency of extreme short-term price spikes.

Several benefits would flow from the type of diminished price volatility that distributed generators would provide. In the short run, less price volatility would reduce the risk of increases in retail utilities' power costs that could jeopardize their financial viability. That situation arose

3. Department of Energy, Energy Information Administration, *Annual Energy Review 2000* (August 2001), Table 8.1.

4. Those numbers do not include mobile generators. See California Energy Commission, *Database of Public Back-Up Generators (BUGS) in California*, available at www.energy.ca.gov/database.

5. Distributed generation is only one means by which customers could adjust their demand for utility-supplied power. Another is a demand-management program that provides incentives to customers to reduce consumption during critical periods.

in the California electricity crisis of 2000 to 2001, when large wholesale price increases forced one utility into bankruptcy.[6] In the long run, reduced volatility would encourage independent (nonutility) generators to accept lower prices in long-term contracts by eliminating opportunities for them to gain "windfall" profits by selling electricity in the short-term spot market.

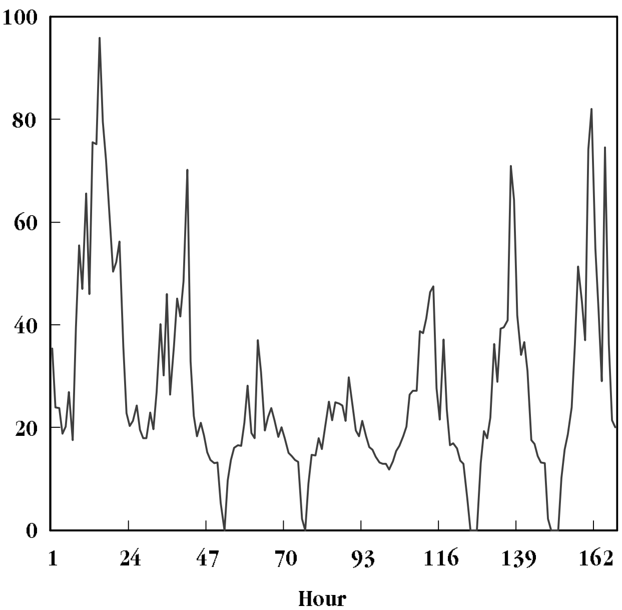
Spot market prices in wholesale electricity markets are highly volatile. During a typical summer week, the average hourly price of electricity in the PJM spot market may vary from as little as zero to more than $100 per megawatt-hour.[7] For example, the zone-weighted average hourly spot price for the week of August 5, 2002, ranged from zero to $96 per megawatt-hour, with an average price of $27.30 per megawatt-hour (*see Figure 3*).

Even those hourly prices understate the volatility of wholesale electricity prices because they are averages of values at different delivery points on the transmission system. Prices at individual delivery points deviate from the system average because of congestion in specific portions of the system during periods of heavy transmission. Such congestion forces the system operator to run more expensive generators in other locations. The differences in the costs of the generation with and without the transmission constraint are captured in the price differentials across delivery points. For example, on Monday, August 5, 2002, when the peak average price was $96 per megawatt-hour, the price at several delivery points was $650 per megawatt-hour.[8]

Figure 3.

Volatility in the Spot Price of Electricity

(Dollars per megawatt-hour)



Source: Congressional Budget Office based on data from the PJM Independent System Operator.

Notes: The figure shows the PJM zone-weighted hourly spot price of electricity over the week of August 5, 2002. PJM is the organization responsible for wholesale power sales and transmission in major portions of five mid-Atlantic states and the District of Columbia. The data are available at www.pjm.com.

Hourly prices can fall as low as zero because some generators that must run continuously, such as nuclear plants, offer to supply electricity regardless of the price. During some hours, those generators' output may exceed the total demand, resulting in a clearing price of zero.

During periods of peak demand, even modest changes in the demand for and supply of wholesale power could significantly reduce electricity prices in regional spot markets. For example, one study estimated that a 5 percent reduction in peak demand in California during 2000 would have lowered wholesale spot prices by more than 50 percent.[9] Another study of emergency demand

6. See Congressional Budget Office, *Causes and Lessons of the California Electricity Crisis* (September 2001), for a detailed discussion of that state's experience.

7. The PJM Independent System Operator is responsible for wholesale power sales and transmission in major portions of five mid-Atlantic states and the District of Columbia.

8. The delivery points that experience extreme prices tend to have deficient transmission capacity, which creates chronic congestion. The high prices provide incentives for investment in additional generation and transmission infrastructure sited in locations that might relieve the congestion.

9. Eric Hirst and Brendan Kirby, *Retail-Load Participation in Competitive Wholesale Electricity Markets* (report prepared for Edison Electric Institute and Project for Sustainable FERC [Federal Energy Regulatory Commission] Energy Policy, January 2001), p. 5.

response in New York during critical periods in 2001 found that a demand reduction of as little as 400 megawatts (1.3 percent of annual peak demand) lowered wholesale prices by 28 percent in certain areas.[10] The widespread adoption of distributed generation could provide an important means for realizing those types of reductions.

Any diminishment in price volatility of the type that distributed generators are likely to produce can yield savings for customers as a group. The reason is that the beneficial operation of distributed generators will tend to reduce prices in long-term contracts for electricity. By operating during periods of extreme price increases, distributed generators would tend to reduce the frequency and duration of those price spikes. Investors in new independent power plants would be more inclined to enter into long-term contracts at lower prices because their opportunity to earn large profits in the spot market would be diminished significantly. Any savings on long-term prices would, under cost-of-service regulations or with retail competition, be passed on to retail customers.

Potential Benefits for the Environment and National Security

Many environmental and energy-conservation advocates believe that distributed generation could offer significant benefits—ones that are not fully reflected in the value of that electricity to the market. Benefits for environmental quality may come from distributed generation's role in promoting renewable energy sources, less-polluting forms of fossil energy, and high-efficiency technologies. Security benefits may come from increasing the geographic dispersion of the nation's electricity infrastructure and from reducing its vulnerability to terrorist attacks that could interrupt electricity service over large areas.

Distributed generation technologies that relied on renewable energy sources could yield environmental benefits in the form of reduced emissions of pollutants and greenhouse gases if those technologies displaced utility-supplied power, much of which is generated from coal. Technologies that relied on conventional fuels would yield environmental benefits if they resulted in a shift to less-polluting energy sources—for example, natural gas rather than coal. High-efficiency technologies could yield benefits by reducing the amount of energy required to produce a unit of electricity.

Security benefits of distributed generation relate to the current vulnerability of the nation's electricity infrastructure to terrorist attacks. Most of the nation's electricity comes from large central generation plants and moves over an extensive network of transmission lines, which would be difficult to defend against a physical attack. The operation of that system relies on telecommunications and computers to relay instructions to dispatch generating units and route power supplies. Those controls are increasingly tied to the on-line operation of regional wholesale markets that balance supply and demand and set prices. If more of the nation's electricity supply originated in the homes and businesses where it was consumed, the adverse consequences of any attack that disrupted the network would be diminished.

Uncertainties and Risks

The prospects for widespread adoption of distributed generation technologies are not at all certain. Nor is it clear that those technologies will be used in ways that achieve their full potential economic benefits. Moreover, this new source of electricity poses a distinct risk of negative impacts that may be difficult to anticipate or expensive to avoid. Those effects include potential degradation in the performance of the electricity distribution network, inequitable and possibly inefficient redistribution of the costs of electricity service among customers, and a decline in environmental quality. Measures to mitigate those adverse impacts could significantly limit the adoption of distributed generation or increase costs to the point at which most applications would no longer be financially viable. In fact, many such restrictions on the use of distributed generators have been imposed and are discussed in the next chapter.

Uncertainty Related to Market Restructuring

The likelihood of achieving the potential benefits from widespread adoption and efficient use of distributed gen-

10. Neenan Associates, "Executive Summary," *NYISO* [New York Independent System Operator] *Price-Responsive Load Program Evaluation Final Report* (January 2002).

eration technologies is closely related to the continued restructuring of the electric power industry. If competitive wholesale markets for electricity develop with nondiscriminatory access and hourly prices determined by supply and demand, those markets will give operators of distributed generators an incentive to run their units when such operation will reduce the overall cost of supplying electricity. But if wholesale markets do not develop efficiently—for example, because of restricted access or regulated prices—the benefits of distributed generation may not be fully realized.

The restructuring of retail electricity markets could also affect the prospects for distributed generation. If state regulators "unbundled" electricity generation from other services (such as transmission and distribution) and introduced competition in the generation portion of the market, then suppliers would be pressured to make their pricing consistent with the pricing in wholesale markets. That development would accelerate the introduction of real-time pricing and other electricity rate offerings that promoted flexible demand, providing additional incentives to operators of distributed generators to run their units efficiently. But if regulators constrained retail competition by restricting price flexibility or by imposing surcharges on customers who adopted distributed generation, then the technology might not achieve its full market potential and operational benefits.

Finally, the restructuring of wholesale and retail markets could reduce the attractiveness of distributed generation to many customers. (See the appendix for a discussion of restructuring and its effect on prices.) If electricity prices fell because of greater competition and initiatives to increase demand flexibility at the retail level, that decline could diminish the value of existing distributed generator systems and reduce the profitability of new ones.

Uncertainty About Market Potential

Besides uncertainty related to market restructuring, other types of uncertainty will affect the potential growth of distributed generation applications. Such uncertainty includes the actual costs of installing and operating distributed generation technologies relative to central power technologies, the actual value to individual customers of improvements in reliability of service, and variations in the financial benefits for individual customers, which are difficult to capture in an overall analysis such as this one.

The costs of the various distributed technologies themselves are uncertain. The two most widely mentioned high-efficiency technologies—microturbines and fuel cells—either are not yet commercially available or are in the early stages of commercialization.[11] Although their proponents predict that installed equipment costs will decline substantially in the future as commercial production increases, such an outcome cannot be known in advance. Other technologies—such as photovoltaic systems—have been in commercial production for some time, but proponents still forecast that their costs will fall considerably as manufacturing processes continue to improve and production increases.

A second uncertainty surrounding the market potential of distributed generation concerns the benefits from improved reliability of service, which are often difficult to value. The main appeal of distributed generation for many customers in the current regulatory environment is that its use can avoid or minimize the effects of electricity service interruptions. On-site generation is often used in hospitals, where interruptions in electric service could endanger patients, and in high-technology companies, where power interruptions could damage sensitive equipment, cause losses of important computer data, or spoil manufacturing processes. Many of those costs are hard to quantify.

Finally, the financial benefits that customers will weigh to decide whether to invest in and operate distributed generators are much more diverse that those summarized here. Conditions will vary widely from customer to customer—depending on such factors as the customer's economic activity, size, location, and load profile—and many technologies will not prove suitable. For example, a large commercial customer with significant air conditioning needs and hot-water requirements, facing a time-of-day tariff with high rates during peak periods, might find it economically beneficial to install a distributed generator to serve part of those needs at peak times while

11. The fuel cell technologies with the greatest potential to reduce costs are not yet commercially available.

producing hot water as a by-product. In contrast, for smaller customers with a flat-rate tariff, the cost to install and operate distributed generation equipment would make it economically unattractive.

Threats to the Performance of Electric Systems

Without adequate upgrades to the electricity supply network, widespread adoption of distributed generation could adversely affect regional electricity distribution systems. For example, with many customers switching their generators on and off, the quality of the power and the reliability of the systems could be degraded. Moreover, because utilities could have difficulty pinpointing the sources of the degradation, they might not be able to allocate to the owners of distributed generators the costs of preventive actions.

It may be difficult to develop economically sound policies on how to pay for any required upgrades in the utility infrastructure to protect against those risks. Experts generally agree that the current risks to the distribution system from the parallel operation of small generators, representing only a small fraction of a local distribution network's capacity, are usually manageable.[12] But the cumulative effects of many generators would be another matter. The utility network might require significant upgrades and additional protective devices to manage distributed generators that could use a large fraction of the local distribution network's capacity.

Traditionally, many utility commissions have adopted a "user-pays" policy under which the interconnection applicant bears the costs of any network upgrades to prevent potential problems. That policy favors early connectors, who can take advantage of excess network capacity; later connectors are at a disadvantage because they must pay for necessary upgrades. Advocates argue that credits for interconnection charges should be given for distributed generation because its use defers investment in transmission and distribution networks. But the deferrals are difficult to quantify and extremely variable from case to case, so it would be hard to craft a set of clear rules for such credits. A policy under which costs were recovered through higher transmission and distribution rates for all customers would conflict with the user-pays policy, which many regulators have adopted on the basis of equity considerations. Moreover, independent generators would have no incentive to locate plants where they would minimize the need for infrastructure upgrades, because the generators would not bear the costs of the upgrades.

Difficulties in Recovering Utility Costs and Paying for Public Benefit Programs

Distributed generation effectively allows customers to bypass utility-supplied power, avoiding various surcharges that are not related to the current cost of production—for example, charges to recover past utility investments (so-called embedded costs) that have proven uneconomic and charges to fund energy-efficiency programs or subsidies to small or low-income users. Increased adoption of distributed generation would limit the ability of regulators to use their ratemaking authority to distribute those costs according to equity considerations. It would also impose the burden of paying for embedded costs on customers who depended most on utility-supplied power.

Historically, state regulators have allowed utilities to set retail prices to recover the actual costs of investments that were deemed prudent and necessary to the provision of electricity, even when subsequent developments made some of those investments uneconomic. For example, in the 1980s, when wholesale electricity prices plummeted, utilities set rates that allowed them to recover the costs of their existing high-priced long-term contracts to secure electricity. State regulators have also frequently used the ratemaking process to achieve certain equity objectives. For example, "baseline" rates are intended to provide a basic level of electricity service at a below-average cost. Regulators often include charges in general tariffs

12. For example, FERC's recent "Advance Notice of Proposed Rulemaking on Standardization of Small Generator Interconnection Agreements and Procedures" (Docket No. RM02-12-000, August 16, 2002) stated that "[a] presumption of 'no impact' will normally be made if the following conditions are met: (1) the project's export of electricity (net of on-site load) would not exceed, cumulatively with all prior small resources on the system, (a) 15 percent of the peak load on a radial feeder or (b) 25 percent of the minimum load on a network link, and (2) the project's capability does not exceed 25 percent of the maximum short circuit potential."

to cover the costs of energy-conservation or low-income assistance programs.[13]

Distributed generation could provide customers with a means to circumvent part of those costs. For example, under tariffs that increase as consumption rises (boosting the cost per kilowatt-hour), a customer could use distributed generation to avoid buying electricity at the higher prices. The financial attractiveness of investment in distributed generators would probably diminish if utilities were allowed to assess distributed generation customers for such costs.

Risks to Air Quality and National Security

The distributed generation technologies with the greatest market potential are probably those fueled by fossil energy (backup generators powered by diesel fuel and cogenerators powered by natural gas), not renewable energy. The potential for customer-owned wind and solar power will probably continue to be realized only in limited circumstances, unless the capital costs of those technologies fall considerably. High-efficiency microturbine and fuel cell technologies are still at the earliest stages of commercialization, so their potential is largely unknown. Thus, the immediate promise of improved air quality from wider adoption of distributed generation may be limited, and improvements would probably come primarily from substituting natural gas- and diesel-fired generators for coal-fired generators. On the downside, those new generators might end up displacing power from units that were already fired by natural gas. And if some generators switched from relatively clean-burning natural gas to diesel, local air quality could worsen.

Another risk is that widespread adoption of gas-fired distributed generators could necessitate construction of additional pipeline capacity. The EIA's Reference Case Mid-Term Energy Forecast projects that electricity generated from natural gas will climb from 17 percent in 2001 to 29 percent in 2025. If that increase largely takes the form of distributed generation near growing population centers, additional pipeline capacity will be needed to supply those generators. Any savings in investments in electricity transmission and distribution networks would be partially offset by the need for investments in new natural gas pipelines.

Other adverse (or at least costly to control) effects also could result. They might include damage from unconventional forms of pollution such as waste heat and noise —problems that have been associated with diesel-powered backup generators and cogeneration plants sited in urban settings. Even windmills have environmental drawbacks, including detracting from the aesthetics of the landscape. Such impacts might not be easy to anticipate or be readily apparent for a small number of units, but the cumulative effect of many dispersed generators could be significant. In geographic areas with strict emissions standards, it would be necessary to inspect distributed generators regularly to monitor their compliance with those standards. Under the scenario of widespread use of small-scale generators envisioned by proponents, the cost of that monitoring could be steep.

13. For example, Pacific Gas and Electric Company's residential tariff includes a charge for "Public Purpose Programs" of 0.4 cents per kilowatt-hour.